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(54)

SYSTEM FOR AND METHOD OF NON-PRIMARY CHANNEL UTILIZATION IN A NETWORK

- (57)

A first device includes at least one processor configured to communicate with the second device using a primary channel, detect occupation on the primary channel by a third device, and communicate with the second device using a secondary channel in response to the
- occupation by the third device. The secondary channel is chosen from a set of channels. The set of channels being determined at least partially in response to information or parameters exchanged during association of the first device and the second device.

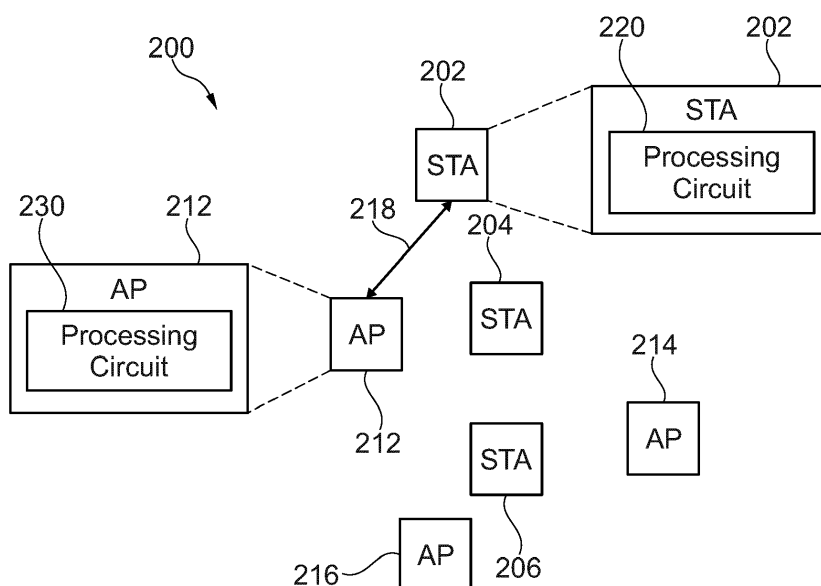


Fig. 2A

Description

Cross-Reference to Related Application

[0001] The present application claims priority to Indian Provisional Patent Application No. 2022-21064890, filed on 12 November 2022 and U.S. Patent Application No. 18/307,391 filed on 26 April 2023, the entire contents of which are incorporated by reference in their entirety.

Field of the Disclosure

[0002] This disclosure generally relates to systems for and methods of communication between a station (STA) and access point (AP) or between other communication devices.

Background of the Disclosure

[0003] In the last few decades, the market for wireless communications devices has grown by orders of magnitude, fueled by the use of portable devices, and increased connectivity and data transfer between all manners of devices. Digital switching techniques have facilitated the large scale deployment of affordable, easy-to-use wireless communication networks. Furthermore, digital and radio frequency (RF) circuit fabrication improvements, as well as advances in circuit integration and other aspects have made wireless equipment smaller, cheaper, and more reliable. Wireless communication can operate in accordance with various standards such as IEEE 802.11x, Bluetooth, global system for mobile communications (GSM), code division multiple access (CDMA), etc. As higher data throughput and other changes develop, newer standards are constantly being developed for adoption, such as a progression from IEEE 802.11n to IEEE 802.11ac to 8-2/11be.

Brief Description of the Drawings

[0004] Various objects, aspects, features, and advantages of the disclosure will become more apparent and better understood by referring to the detailed description taken in conjunction with the accompanying drawings, in which like reference characters identify corresponding elements throughout. In the drawings, like reference numbers generally indicate identical, functionally similar, and/or structurally similar elements.

FIG. 1A is a block diagram depicting a network environment including one or more access points in communication with one or more devices or stations, according to some embodiments.

FIGS. 1B and 1C are block diagrams depicting computing devices useful in connection with the methods and systems described herein, according to some embodiments.

FIG. 2A is a block diagram depicting a network including access points (APs) and stations (STAs), according to some embodiments.

FIG. 2B is a more detailed block diagram of a STA configured for non-primary channel utilization operations according to some embodiments.

FIG. 3 is a block diagram of a wider bandwidth including sub bands for use in the network illustrated in FIG. 2A, according to some embodiments.

FIG. 4 is a block diagram depicting a transmitting device and a receiving device configured for non-primary channel utilization according to some embodiments.

FIG. 5 is a flow diagram illustrating an example transmitting device operation for non-primary channel utilization setup operations for the network illustrated in FIG. 2A, according to some embodiments.

FIG. 6 is a flow diagram illustrating an example receiving device operation for non-primary channel utilization setup operations for the network illustrated in FIG. 2A, according to some embodiments.

[0005] The details of various embodiments of the methods and systems are set forth in the accompanying drawings and the description below.

Detailed Description

[0006] The following IEEE standard(s), including any draft versions of such standard(s) and draft amendments to such standards, are hereby incorporated herein by reference in their entirety and are made part of the present disclosure for all purposes: WiFi Alliance standards and IEEE 802.11 standards including but not limited to IEEE 802.11aTM, IEEE 802.11bTM, IEEE 802.11gTM, IEEE 802.11nTM, 802.11beTM and IEEE P802.11acTM standards. Although this disclosure can reference aspects of these standard(s), the disclosure is in no way limited by these standard(s).

[0007] For purposes of reading the description of the various embodiments below, the following descriptions of the sections of the specification and their respective contents can be helpful:

- Section A describes a network environment and computing environment which can be useful for practicing embodiments described herein; and
- Section B describes embodiments of non-primary channel utilization protocols and methods and devices using such protocols and methods.

[0008] Various embodiments disclosed herein are re-

lated to a protocol for using non-primary channels for communication. In some embodiments, systems and methods utilize information from a handshake or association operation to automatically select non-primary channels for communication. The protocol can be part of an Extremely High Throughput (EHT) protocol for a network (e.g., an IEEE 802.11be standard network and beyond) in some embodiments. In some embodiments, the systems and methods communicate packets on idle portions of the bandwidth outside of the primary channel (e.g., on a secondary channel) without requiring primary channel communications to set up the communication on the bandwidth outside of the primary channel. For example, if a primary 20 megahertz (MHz) bandwidth channel is busy, a device, such as a STA or AP, is configured to transmit on idle portions of the operating bandwidth which provides advantages over conventional 802.11 standard devices. In some embodiments, the systems and methods switch with little communication overhead to idle non-primary channels to more efficiently utilize the bandwidth of a network (e.g., an 802.11 network).

[0009] The inefficient usage of bandwidth causes loss of bandwidth utilization, and the loss increases with increases in operating bandwidth. For example, in an 802.11 standard network, a busy 20MHz primary channel in a 320MHz bandwidth channel prevents a STA from accessing the remaining 200MHz bandwidth that is idle. In some embodiments, the systems and methods of non-primary channel utilization operate in the same bands as unlicensed technologies, such as licensed assisted access (LAA) and new radio - unlicensed (NR-U) technologies, and yet meet or accommodate IEEE 802.11 standard requirements and/or provide a 20MHz channel for system information and/or beacon signals. In some embodiments, the systems and methods employ a protocol that is backward compatible with legacy devices that operate only on the primary 20MHz channel. The communications on the non-primary channel can be to or from a client device (e.g., a STA) or AP or can be between other types of communication devices in some embodiments. The client device or AP can be implemented in a device including one or more integrated circuits (ICs) packaged in an IC package.

[0010] Some embodiments relate to first device for communicating with a second device. The first device includes at least one processor or circuitry configured to communicate with the second device using a primary channel, detect occupation on the primary channel by a third device, and communicate with the second device using a secondary channel in response to the occupation by the third device. The secondary channel is chosen from a set of channels. The set of channels is determined at least partially in response to information or parameters exchanged during association of the first device and the second device. Occupation may refer to a device using a channel such that communication by other devices on the channel is adversely affected (e.g., due to interference, noise, etc.) in some embodiments. In some em-

bodiments, occupation can be caused by an overlapping basic service set (OBSS). Occupation can be detected by sensing received signal intensity on the channel or carrier sensing in some embodiments. Occupation can be detected by operations including but not limited to energy detection, a clear channel assessment (CCA) operation and/or a preamble decode operation in some embodiments.

[0011] In some embodiments, the at least one processor is further configured to communicate with the second device using the primary channel when the occupation by the third device is completed. In some embodiments, the first device includes a station (STA) device communicating via the 802.11be protocol. In some embodiments, information includes a first capability of the first device and a second capability of the second device. A capability may refer to an ability of a device to perform a communication task including but not limited to a parallel or sequential preamble decode operation or a parallel or sequential CCA in some embodiments. In some embodiments, the first capability is a capability to perform a preamble decode operation in parallel on multiple channels. In some embodiments, a number of the channels in the set of the channels is less than or equal to a number of the multiple channels upon which the preamble decode operation is performed in parallel. In some embodiments, the second capability includes a capability to perform a clear channel assessment operation in parallel on multiple channels. In some embodiments, the clear channel assessment (CCA) operation includes a virtual clear channel assessment operation. A CCA operation or clear channel assessment may refer to a procedure for determining whether a channel or portions thereof are idle or not in some embodiments. The CCA operation can include carrier sensing and/or energy detection on the channel or portions thereof in some embodiments. The CCA can be performed in an unlicensed spectrum because the device may not have exclusive access to that spectrum and generally has to determine if the channel is clear through direct measurements, observations and detection mechanisms, such as, for example CCA in some embodiments. An energy detect operation may refer to an operation where a level of energy on a channel is detected to determine whether a channel is busy, occupied or otherwise usable/unuseable in some embodiments.

[0012] A preamble decode operation may refer to an operation performed by any device to determine or decode a preamble to detect a presence of a packet on a channel in some embodiments. A virtual clear channel assessment operation may refer a procedure that instructs a device to indicate that the medium is busy, for a time period that is longer than the device would conventionally indicate it to be busy for a single transmission (e.g., a STA is instructed to assert a CCA operation for the entire duration of a whole frame exchange sequence) in some embodiments. A capability to perform a preamble decode operation in parallel on multiple channels may

refer to an ability to perform a preamble decode operation on more than one channel at the same time, nearly the same time, or in a same time period in some embodiments. A capability to perform a clear channel assessment operation in parallel on multiple channels may refer to an ability to perform a CCA operation on more than one channel at the same time, nearly the same time, or in a same time period in some embodiments.

[0013] In some embodiments, the second capability includes a capability that does not include a capability to perform a clear channel assessment operation in parallel on multiple channels. The second capability includes a capability to perform a clear channel assessment operation on a single channel and the clear channel assessment operation may include a virtual clear channel assessment operation.

[0014] In some embodiments, the set of channels are channels used for a data transfer. In some embodiments, the set of channels are channels used for a data transfer, and the first capability includes a capability that does not perform a preamble decode operation in parallel on multiple channels. A data transfer may refer to a communication of data on one or more channels or bandwidths in some embodiments.

[0015] Some embodiments relate to a first device for communicating on a network. The first device include at least one processor or circuitry configured to communicate using a secondary channel after completing association on a primary channel. The secondary channel is selected at least partially in response to a parameter exchanged during the association. The parameter indicates a capability to perform a preamble decode operation in parallel on multiple channels, a capability to perform a clear channel assessment operation in parallel on multiple channels, a capability for a clear channel assessment operation that does not include a capability to perform the clear channel assessment operation in parallel on multiple channels, or a capability for a preamble decode operation that does not perform the preamble decode operation in parallel on multiple channels.

[0016] In some embodiments, the first device includes a station (STA) device communicating via the 802.11 be protocol. In some embodiments, the parameter comprises a delay time. In some embodiments, the delay time is to allow a receiver to retune for preamble detection on a different channel.

[0017] In some embodiments, the secondary channel is a 20 MHz channel. In some embodiments, the secondary channel is selected from a list of anchor channels determined at least partially in response to the parameter.

[0018] Some embodiments relate to a method of switching from a primary channel to a secondary channel. The method includes associating with a first device using the primary channel, detecting occupation on the primary channel by a second device, and communicating with the first device using the secondary channel at least in response to the occupation by the second device. The

secondary channel is chosen at least in part in response to a parameter exchanged during association using the primary channel. The parameter indicates a capability to perform a preamble decode operation in parallel on multiple channels, a capability to perform a clear channel assessment operation in parallel on multiple channels, a capability for a clear channel assessment that does not include a capability to perform the clear channel assessment operation in parallel on multiple channels, or a capability for a preamble decode operation that does not perform the preamble decode operation in parallel on multiple channels.

[0019] In some embodiments, the method further includes performing a preamble decode operation before communicating with the second device on the secondary channel. In some embodiments, the method further includes performing a clear channel assessment operation on the secondary channel before communicating with the second device on the secondary channel.

[0020] A channel may refer to any portion of the electromagnetic spectrum used to communicate data in some embodiments. The portions can have various bandwidths and can be combined to form wider bandwidths or channels. Channels can have 5 MHz spacing about a center frequency and can occupy a band of at least 20 MHz in some embodiments. Authentication and association under 802.11 standards provides a method for supplying different levels of access to client devices in a network. Connection between an AP and a STA must generally be authenticated by and associated with an AP before data packets can be exchanged using the connection. A primary channel may refer to a portion of the electromagnetic spectrum used to authorize and/or authenticate connections in some embodiments. A primary channel may also refer to a channel which is monitored for activity to determine when channel access attempts are allowed according to some channel access protocol, for example, 802.11 EDCA in some embodiments. In some embodiments, the primary channel is a channel for transmitting beacon signals and other management frames. The primary channel can be indicated in a primary channel field in some embodiments. The terms primary channel and primary control channel are used interchangeably herein. A secondary channel may refer to a channel that is not a primary channel.

[0021] Authentication may refer to a procedure for how a client device gains access to the network in some embodiments. Authentication provides proof of identity to ensure the client is allowed access to the network in some embodiments. Association may refer to a handshaking or other procedure for associating two devices in some embodiments. In some embodiments, association refers to a procedure for a client device that has been authenticated to become associated with an AP. Association allows the network to determine where to send data that is intended for a client device (e.g., data is sent through the AP with which the client device is associated) in some embodiments. Generally, a client device is only associ-

ated with a single AP. Association can involve an exchange of parameters and information for coordinating communication between the devices (e.g., capability information and secondary channel selection information). Association can involve beacon frames, response frames, and other management frames in some embodiments.

[0022] According to some example network operations, an AP uses a primary control channel within a wider bandwidth (e.g., 40/80/160/320 MHz sub bands or channels). Authentication and association are performed over at least the primary control channel. For example, management frames including but not limited to beacon, probe response, deauthentication/disassociation frames are communicated on the primary control channel (e.g., 20MHz sub band) of a wider bandwidth.

[0023] A primary channel or primary control channel may refer to a channel contained within a bandwidth of a larger channel (e.g., wider bandwidth) that includes a secondary bandwidth channel or secondary channel in some embodiments. For example, a link may include a set of contiguous 20 MHz channels where one of the channels is a primary channel. In some embodiments, the primary channel uses an upper half or lower half of the bandwidth of the wider channel, and the secondary channel uses the remaining half of the bandwidth of the wider channel. In some embodiments, the bandwidths of the primary channel and the secondary channel are not equal, and the primary channel occupies a sub band and one or more secondary channels occupy the remaining sub bands in the wider bandwidth. In some embodiments, the secondary channel has more or less bandwidth than the primary channel. In some embodiments, the primary channel is used for client devices that only support a smaller channel bandwidth (e.g., 20 MHz) while the primary channel and the secondary channel(s) can be used for client devices that support wider channel capabilities. In some embodiments, there are multiple secondary bandwidth channels and a single primary bandwidth channel, each having the same bandwidth. The terms primary and secondary do not connote a specific priority and can be interchanged with first and second and vice versa in some embodiments.

[0024] In some embodiments, the primary channel is a common channel of operation for all stations (STAs) that are members of the basic service set (BSS). For example, in a 20 MHz, 40 MHz, 80 MHz, 160 MHz or 80+80 MHz, 320 MHz bandwidth BSS, the primary channel is a 20 MHz channel. The primary channel is used for transmitting all the management frames and for determining whether an access attempt is allowed while the secondary channels are neighboring channels of the primary channel in some embodiments. The secondary channels can combine with the primary channel to form another primary channel of the next wider bandwidth.

[0025] A frame may refer to a digital data transmission unit. For example, a frame may refer to a container for a single network packet. A data frame may refer to a frame

that contains data. An ACK frame may refer to an acknowledgement message that acknowledges the receipt of a frame, and a block ACK frame may refer to an acknowledgement message that acknowledges the receipt of a number of frames. Parameters for use in non-primary channel utilization can be provided in management frames and acknowledge frames. Management frames may refer to any frame used to provide data control or coordinate communications in some embodiments. Management frames can include frames provided during association and authentication as well as other handshaking and messaging.

A. Computing and Network Environment

[0026] Prior to discussing specific embodiments of the present solution, it can be helpful to describe aspects of the operating environment as well as associated system components (e.g., hardware elements) in connection with the methods and systems described herein. Referring to FIG. 1A, an embodiment of a network environment is depicted. In brief overview, the network environment includes a wireless communication system that includes one or more access points (APs) or network devices 106, one or more client devices (e.g., STAs) or wireless communication devices 102 and a network hardware component or network hardware 192. The wireless communication devices 102 can for example include laptop computers, tablets, personal computers, and/or cellular telephone devices. The details of an embodiment of each station or wireless communication device 102 and AP or network device 106 are described in greater detail with reference to FIGS. 1B and 1C. The network environment can be an ad hoc network environment, an infrastructure wireless network environment, a subnet environment, etc. in one embodiment. The network devices 106 or APs can be operably coupled to the network hardware 192 via local area network connections. Network devices 106 are 5G base stations in some embodiments. The network hardware 192, which can include a router, gateway, switch, bridge, modem, system controller, appliance, etc., can provide a local area network connection for the communication system. Each of the network devices 106 or APs can have an associated antenna or an antenna array to communicate with the wireless communication devices in its area. The wireless communication devices 102 can register with a particular network device 106 or AP to receive services from the communication system (e.g., via a SU-MIMO or MU-MIMO configuration). For direct connections (e.g., point-to-point communications), some wireless communication devices can communicate directly via an allocated channel and communications protocol. Some of the wireless communication devices 102 can be mobile or relatively static with respect to network device 106 or AP.

[0027] In some embodiments, a network device 106 or AP includes a device or module (including a combination of hardware and software) that allows wireless commu-

nication devices 102 to connect to a wired network using wireless-fidelity (WiFi), or other standards. A network device 106 or AP can sometimes be referred to as a wireless access point (WAP). A network device 106 or AP can be implemented (e.g., configured, designed and/or built) for operating in a wireless local area network (WLAN). A network device 106 or AP can connect to a router (e.g., via a wired network) as a standalone device in some embodiments. In other embodiments, network device 106 or AP can be a component of a router. Network device 106 or AP can provide multiple devices access to a network. Network device 106 or AP can, for example, connect to a wired Ethernet connection and provide wireless connections using radio frequency links for other devices 102 to utilize that wired connection. A network device 106 or AP can be implemented to support a standard for sending and receiving data using one or more radio frequencies. Those standards, and the frequencies they use can be defined by the IEEE (e.g., IEEE 802.11 standards). A network device 106 or AP can be configured and/or used to support public Internet hotspots, and/or on a network to extend the network's Wi-Fi signal range.

[0028] In some embodiments, the access points or network devices 106 can be used for (e.g., in-home, in-vehicle, or in-building) wireless networks (e.g., IEEE 802.11, Bluetooth, ZigBee, any other type of radio frequency based network protocol and/or variations thereof). Each of the wireless communication devices 102 can include a built-in radio and/or is coupled to a radio. Such wireless communication devices 102 and /or access points or network devices 106 can operate in accordance with the various aspects of the disclosure as presented herein to enhance performance, reduce costs and/or size, and/or enhance broadband applications. Each wireless communication device 102 can have the capacity to function as a client node seeking access to resources (e.g., data, and connection to networked nodes such as servers) via one or more access points or network devices 106.

[0029] The network connections can include any type and/or form of network and can include any of the following: a point-to-point network, a broadcast network, a telecommunications network, a data communication network, a computer network. The topology of the network can be a bus, star, or ring network topology. The network can be of any such network topology as known to those ordinarily skilled in the art capable of supporting the operations described herein. In some embodiments, different types of data can be transmitted via different protocols. In other embodiments, the same types of data can be transmitted via different protocols.

[0030] The communications device(s) 102 and access point(s) or network devices 106 can be deployed as and/or executed on any type and form of computing device, such as a computer, network device or appliance capable of communicating on any type and form of network and performing the operations described herein. FIGS. 1B and 1C depict block diagrams of a computing

device 100 useful for practicing an embodiment of the wireless communication devices 102 or network device 106. As shown in FIGS. 1B and 1C, each computing device 100 includes a processor 121 (e.g., central processing unit), and a main memory unit 122. As shown in FIG. 1B, a computing device 100 can include a storage device 128, an installation device 116, a network interface 118, an I/O controller 123, display devices 124a-124n, a keyboard 126 and a pointing device 127, such as a mouse. The storage device 128 can include an operating system and/or software. As shown in FIG. 1C, each computing device 100 can also include additional optional elements, such as a memory port 103, a bridge 170, one or more input/output devices 130a-130n, and a cache memory 140 in communication with the central processing unit or processor 121.

[0031] The central processing unit or processor 121 is any logic circuitry that responds to and processes instructions fetched from the main memory unit 122. In many embodiments, the central processing unit or processor 121 is provided by a microprocessor unit, such as: those manufactured by Intel Corporation of Santa Clara, California; those manufactured by International Business Machines of White Plains, New York; or those manufactured by Advanced Micro Devices of Sunnyvale, California. The computing device 100 can be based on any of these processors, or any other processor capable of operating as described herein.

[0032] Main memory unit 122 can be one or more memory chips capable of storing data and allowing any storage location to be directly accessed by the microprocessor or processor 121, such as any type or variant of Static random access memory (SRAM), Dynamic random access memory (DRAM), Ferroelectric RAM (FRAM), NAND Flash, NOR Flash and Solid State Drives (SSD). The main memory unit 122 can be based on any of the above described memory chips, or any other available memory chips capable of operating as described herein. In the embodiment shown in FIG. 1B, the processor 121 communicates with main memory unit 122 via a system bus 150 (described in more detail below). FIG. 1C depicts an embodiment of a computing device 100 in which the processor communicates directly with main memory unit 122 via a memory port 103. For example, in FIG. 1C the main memory unit 122 can be DRDRAM.

[0033] FIG. 1C depicts an embodiment in which the main processor 121 communicates directly with cache memory 140 via a secondary bus, sometimes referred to as a backside bus. In other embodiments, the main processor 121 communicates with cache memory 140 using the system bus 150. Cache memory 140 typically has a faster response time than main memory unit 122 and is provided by, for example, SRAM, BSRAM, or EDRAM. In the embodiment shown in FIG. 1C, the processor 121 communicates with various I/O devices 130 via a local system bus (e.g., system bus 150). Various buses can be used to connect the central processing unit or processor 121 to any of the I/O devices 130, for ex-

ample, a VESA VL bus, an ISA bus, an EISA bus, a Micro Channel Architecture (MCA) bus, a PCI bus, a PCI-X bus, a PCI-Express bus, or a NuBus. For embodiments in which the I/O device is a video display 124, the processor 121 can use an Advanced Graphics Port (AGP) to communicate with the display 124. FIG. 1C depicts an embodiment of a computer or computer system 100 in which the main processor 121 can communicate directly with I/O device 130b, for example via HYPERTRANSPORT, RAPIDIO, or INFINIBAND communications technology. FIG. 1C also depicts an embodiment in which local busses and direct communication are mixed: the processor 121 communicates with I/O device 130a using a local interconnect bus while communicating with I/O device 130b directly.

[0034] A wide variety of I/O devices 130a-130n can be present in the computing device 100. Input devices include keyboards, mice, track pads, trackballs, microphones, dials, touch pads, touch screen, and drawing tablets. Output devices include video displays, speakers, inkjet printers, laser printers, projectors and dye-sublimation printers. The I/O devices can be controlled by an I/O controller 123 as shown in FIG. 1B. The I/O controller can control one or more I/O devices such as a keyboard 126 and a pointing device 127, e.g., a mouse or optical pen. Furthermore, an I/O device can also provide storage and/or an installation medium for the computing device 100. In still other embodiments, the computing device 100 can provide USB connections (not shown) to receive handheld USB storage devices such as the USB Flash Drive line of devices manufactured by Twintech Industry, Inc. of Los Alamitos, California.

[0035] Referring again to FIG. 1B, the computing device 100 can support any suitable installation device 116, such as a disk drive, a CD-ROM drive, a CD-R/RW drive, a DVD-ROM drive, a flash memory drive, tape drives of various formats, USB device, hard-drive, a network interface, or any other device suitable for installing software and programs. The computing device 100 can further include a storage device, such as one or more hard disk drives or redundant arrays of independent disks, for storing an operating system and other related software, and for storing application software programs such as any program or software 120 for implementing (e.g., configured and/or designed for) the systems and methods described herein. Optionally, any of the installation devices 116 could also be used as the storage device. Additionally, the operating system and the software can be run from a bootable medium.

[0036] Furthermore, the computing device 100 can include a network interface 118 to interface to a network through a variety of connections including, but not limited to, standard telephone lines, LAN or WAN links (e.g., 802.11, T1, T3, 56kb, X.25, SNA, DECNET), broadband connections (e.g., ISDN, Frame Relay, ATM, Gigabit Ethernet, Ethernet-over-SONET), wireless connections, or some combination of any or all of the above. Connections can be established using a variety of communication pro-

ocols (e.g., TCP/IP, IPX, SPX, NetBIOS, Ethernet, ARC-NET, SONET, SDH, Fiber Distributed Data Interface (FDDI), RS232, IEEE 802.11, IEEE 802.11a, IEEE 802.11b, IEEE 802.11g, IEEE 802.11n, IEEE 802.11ac, IEEE 802.11ad, CDMA, GSM, WiMax and direct asynchronous connections). In one embodiment, the computing device 100 communicates with other computing devices 100' via any type and/or form of gateway or tunneling protocol such as Secure Socket Layer (SSL) or Transport Layer Security (TLS). The network interface 118 can include a built-in network adapter, network interface card, PCMCIA network card, card bus network adapter, wireless network adapter, USB network adapter, modem or any other device suitable for interfacing the computing device 100 to any type of network capable of communication and performing the operations described herein.

[0037] In some embodiments, the computing device 100 can include or be connected to one or more display devices 124a-124n. As such, any of the I/O devices 130a-130n and/or the I/O controller 123 can include any type and/or form of suitable hardware, software, or combination of hardware and software to support, enable or provide for the connection and use of the display device(s) 124a-124n by the computing device 100. For example, the computing device 100 can include any type and/or form of video adapter, video card, driver, and/or library to interface, communicate, connect or otherwise use the display device(s) 124a-124n. In one embodiment, a video adapter can include multiple connectors to interface to the display device(s) 124a-124n. In other embodiments, the computing device 100 can include multiple video adapters, with each video adapter connected to the display device(s) 124a-124n. In some embodiments, any portion of the operating system of the computing device 100 can be configured for using multiple display devices 124a-124n. In further embodiments, an I/O device 130 can be a bridge between the system bus 150 and an external communication bus, such as a USB bus, an Apple Desktop Bus, an RS-232 serial connection, a SCSI bus, a FireWire bus, a FireWire 800 bus, an Ethernet bus, an AppleTalk bus, a Gigabit Ethernet bus, an Asynchronous Transfer Mode bus, a Fibre Channel bus, a fiber optic bus, a Serial Attached small computer system interface bus, a USB connection, or a HDMI bus.

[0038] A computing device 100 of the sort depicted in FIGS. 1B and 1C can operate under the control of an operating system, which controls scheduling of tasks and access to system resources. The computing device 100 can be running any operating system such as any of the versions of the MICROSOFT WINDOWS operating systems, the different releases of the Unix and Linux operating systems, any version of the MAC OS for Macintosh computers, any embedded operating system, any real-time operating system, any open source operating system, any proprietary operating system, any operating systems for mobile computing devices, or any other operating system capable of running on the computing device and performing the operations described herein.

Typical operating systems include, but are not limited to: Android, produced by Google Inc.; WINDOWS 7, 8 and 10, produced by Microsoft Corporation of Redmond, Washington; MAC OS, produced by Apple Computer of Cupertino, California; WebOS, produced by Research In Motion (RIM); OS/2, produced by International Business Machines of Armonk, New York; and Linux, a freely-available operating system distributed by Caldera Corp. of Salt Lake City, Utah, or any type and/or form of a Unix operating system, among others.

[0039] The computer system or computing device 100 can be any workstation, telephone, desktop computer, laptop or notebook computer, server, handheld computer, mobile telephone or other portable telecommunications device, media playing device, a gaming system, mobile computing device, or any other type and/or form of computing, telecommunications or media device that is capable of communication. In some embodiments, the computing device 100 can have different processors, operating systems, and input devices consistent with the device. For example, in one embodiment, the computing device 100 is a smart phone, mobile device, tablet or personal digital assistant. Moreover, the computing device 100 can be any workstation, desktop computer, laptop or notebook computer, server, handheld computer, mobile telephone, any other computer, or other form of computing or telecommunications device that is capable of communication and that has sufficient processor power and memory capacity to perform the operations described herein.

[0040] Aspects of the operating environments and components described above will become apparent in the context of the systems and methods disclosed herein.

B. Non-primary Channel Utilization

[0041] Disclosed herein are systems for and methods that can be used in communication systems including but not limited to Wi-Fi networks (e.g., IEEE 802.11 standard networks). With reference to FIG. 2A, a wireless communication network or system 200 includes client devices or STAs 202, 204, and 206 and APs 212, 214, and 216. STAs 202, 204, and 206 and APs 212, 214, and 216 can be used in the systems discussed with reference to FIGS. 1A-C.

[0042] Any number of STAs 202, 204, and 206 and APs 212, 214, and 216 can be used in the network or system 200. A station or STA may refer to any device for communicating in communication system 200 and includes but is not limited to a fixed, portable, or mobile laptop, desktop personal computer, personal digital assistant, work station, wearable device, smart phone, or Wi-Fi phone. A STA (e.g., client device) can connect to another STA in some embodiments.

[0043] An access point or AP may refer to a device for communicatively coupling one or more non-AP devices (e.g., a client device or STA) to a network in some embodiments. In some embodiments, an AP may enable

non-AP devices to connect and communicate with a network. In some embodiments, an AP is a wireless access point (WAP) configured to enable wireless communication between non-AP devices. An AP includes but is not limited to a mobile, portable, or fixed hot spot, router, bridge, or other communication device. An AP can provide services to a STA, such as serving as a connection point to another network, or to another AP or STA.

[0044] STAs 202, 204, and 206 and APs 212, 214, and 216 can each include a wireless transceiver and a various modules for communicating via connections. The modules can be software (e.g., firmware) and/or hardware components. In some embodiments, each of STAs 202, 204, and 206 and APs 212, 214, and 216 includes an IEEE 802.11 standard conformant media access control (MAC) layer circuit and physical (PHY) layer interface to the wireless medium and can be part of a larger device or system. In some embodiments, each of STAs 202, 204, and 206 and APs 212, 214, and 216 operates according to other standards than the IEEE 802.11 standard. In some embodiments, STAs 202, 204, and 206 and APs 212, 214, and 216 can communicate directly to each other (e.g., via direct connections outside of the network associated with system 200).

[0045] A connection for wireless communication can be established between at least one of STAs 202, 204, and 206 and APs 212, 214, and 216 after authentication and association. For example, STA 202 has a connection 218 to AP 212. STAs 202, 204, and 206 each include circuitry (e.g., a processor or processing circuit 230), and APs 212, 214, and 216 each include circuitry (e.g., a processing circuit 230) for establishing and cancelling the connection 218 and communicating data across the connection 218. The connection 218 is a wireless connection formed using an association and authorization operation in some embodiments. Connection 218 can be used to communicate data such as a frame. The connection 218 can be in any type and/or form. In some embodiments, data can be transmitted via different protocols on connection 218.

[0046] Components of STAs 202, 204, and 206 and APs 212, 214, and 216 can be provided as one or more integrated circuits (IC) in an IC package. The IC package can be a single chip package or a multichip module. STAs 202, 204, and 206 and APs 212, 214, and 216 operating according to the 802.11be standard may support 320 MHz as the maximum bandwidth of operation on any one link in some embodiments. Non-AP devices (shown as device(s) 102 in FIG. 1A), such as STAs 202, 204, and 206 may support a bandwidth less than 320MHz. Accordingly, an AP or network device 106 may utilize a channel switching protocol to improve network traffic (e.g., uplink traffic and downlink traffic) from the AP or network device 106 to the non-AP(s) or wireless communication devices 102 (FIG. 1C).

[0047] In some embodiments, system 200 may operate on one or more links. For example, an AP 212 that operates on more than one link is an AP Multi Link Device

(AP MLD). An AP MLD operating on two links typically utilizes one 5 gigahertz (GHz) link and one 6 GHz link. In some embodiments, a 5 GHz link is 160 MHz and narrower in bandwidth. In some embodiments, a 6 GHz link is up to 320 MHz in bandwidth. In some embodiments, the AP MLD may, optionally, have an additional 2.4 GHz link. In some embodiments, the 2.4 GHz link has a narrower bandwidth than the 5 and 6 GHz links. STA 208 operating on a link with an AP 212 where the STA operating bandwidth is narrower than the AP bandwidth on that link may be configured to switch between primary and secondary channels of the AP operating bandwidth. For example, a 320 MHz operating bandwidth of an AP may be divided into a 160 MHz primary (160P) sub channel and a 160 MHz Secondary (160S) sub channel. It should be understood that other bandwidth values are possible. For example, a 160 MHz operating channel may be divided into 4x 40 MHz sub channels, a first sub channel of which is the primary channel and the others are secondary channels. In some embodiments, the width of the sub channels can be 20 MHz or 40 MHz or 80 MHz or 160 MHz, etc., while the width of the operating channel can be 40 MHz, 80 MHz, 160 MHz, 320 MHz, etc. In some embodiments, the sub channels are broad-band wireless access (BWA) sub channels.

[0048] In some embodiments, STA 208 associated with an AP 212 normally operates on a portion of the entire operating channel which includes the primary 20 MHz sub channel or channel that is designated by the AP 212 as the primary 20 MHz channel. When, for example, two 160 MHz STAs are associated with an AP 212 operating a 320 MHz channel, those two STAs will operate on the same 160 MHz sub channel of the 320 MHz operating channel. Because the 20 MHz primary exists in only one location and both STAs must include that 20 MHz primary channel in a respective operating width. A STA that can switch from the primary sub channel or channel to operate, at least temporarily, on a different sub channel or channel that does not include the primary 20 MHz sub channel or channel. Such an STA indicates this capability when associating with an AP. The terms sub channels and channels and bandwidth and sub bandwidth can be used interchangeably in some embodiments.

[0049] For example for a 320 megahertz bandwidth for a primary channel and secondary channels, each 20 MHz channel can be available or not available independently because there are other devices which operate with smaller bandwidths (e.g., other technologies - the granularity of access is 20 megahertz in the unlicensed spectrum for some technologies and transmission powers). A use of a particular 20 megahertz channel can restrict Wi-Fi channel access.

[0050] Referring to FIG. 2B, a STA 208 is configured for non-primary channel utilization according to some embodiments. In some embodiments, the STA 208 includes a network interface 210, processing circuit 230, a channel switching module 238, a receiver 240, and a

transmitter 242. The processing circuit 230 includes a processor 234 and a memory 236. Processing circuit 230 is any circuitry or components that can perform logic and communication processing for STA 208. AP 212 can have a similar architecture and components as STA 208 and be configured for non-primary channel utilization. STAs 202, 204, and 206 and APs 214, and 216 can have similar architecture and components to STA 208.

[0051] In some embodiments, the processing circuit 230 is implemented as a field-programmable gate array, an application-specific integrated circuit, hardware, a software executing processor, or state machines. In some embodiments, the processing circuit 230 is part of layers (e.g., MAC, network, PHY layers) of IEEE 802.11 standard devices. The processing circuit 230 can be configured to perform communication operations, non-primary channel utilization and setup therefor, channel selection, frame building and processing, association operations, authorization operations, connection setup, disassociation operations, and deauthentication operations in some embodiments. Instructions for the processing circuit 230 can be stored in a non-transitory medium such as memory 236 in some embodiments. Processing circuit 230 of AP 212 is similar to processing circuit 230.

[0052] The memory 236 may be one or more devices (e.g., RAM, ROM, Flash memory, hard disk storage) for storing data and/or computer code for completing and/or facilitating the various processes described herein. The memory 236 may be or include non-transient volatile memory, non-volatile memory, and non-transitory computer storage media. Memory 236 may include database components, object code components, script components, or any other type of information structure for supporting the various activities and information structures described herein. Memory 236 may be communicably coupled to the processor 234 and include computer code or instructions for executing one or more processes described herein. The processor 234 may be implemented as one or more application specific integrated circuits (ASICs), hardware, field programmable gate arrays (FPGAs), a group of processing components, and a software executing processor, state machines or other suitable electronic processing components. As such, STA 208, AP 212 or network device 106 (FIGS 1A-C) is configured to run a variety of modules and/or programs and store associated data in a database of the memory 236. The modules (e.g., module 238) can be implemented in AP software (e.g., MAC layer or PHY layer software) or STA software (e.g., MAC layer or PHY layer software).

[0053] In some embodiments, the network interface 210 is structured and used to establish connections with other computing systems and devices (e.g., wireless communication device(s) 102, network hardware 192, other access points or network devices 106 (FIGS. 1A-C) via a network (e.g., WAN connection, LAN connection, WLAN connection, etc.). The network interface 210 includes program logic that facilitates connection of the STA 208 to the network connections. For example, the

network interface 210 may include any combination of a wireless network transceiver (e.g., a cellular modem, a Bluetooth transceiver, a Wi-Fi transceiver, transmitter 242, etc.) and/or a wired network transceiver (e.g., an Ethernet transceiver). In some arrangements, the network interface 210 includes the hardware (e.g., processor, memory, and so on) and machine-readable media sufficient to support communication over multiple channels of data communication. A network interface or network interface circuit may refer to any circuit or circuitry (with or without software) configured to establish connections with other computing systems. The network interface 210 can include a physical layer circuitry necessary for communicating with a data link layer standard, such as Ethernet or Wi-Fi. The circuit can prepare and control the flow of data on the network.

[0054] In various embodiments, transmitter 242 is a transmitter module (sometimes referred to as a "transmitter circuit"). The transmitter 242 can be configured to provide or transmit wireless signals representing data or frames. A transmitter may refer to any circuit for communicating radio frequency data, such as frames. Transmitter 242 can include circuitry for encoding, modulating, processing and providing frames as wireless signals.

[0055] In various embodiments, receiver 240 is a receiver module (sometimes referred to as a "receiver circuit"). The receiver 240 can be configured to receive wireless signals representing data or frames. A receiver may refer to any circuit for communicating radio frequency data, such as frames. Receiver 240 can include circuitry for decoding, demodulating, processing and providing frames derived from transmitted wireless signals.

[0056] In some embodiments, processing circuit 230 includes a channel switching module 238 (sometimes referred to as a "channel switching circuit 238"). The channel switching module 238 can be configured to communicatively couple with one or more client devices or STA 208 (e.g., non-AP devices) and can be configured to allocate the one or more STAs 202, 204, 206, and 208 and APs 212, 214, and 216 on one of a primary channel or a secondary channel (e.g., an anchor channel). In particular, the channel switching module 238 can be configured to perform the non-primary channel utilization operations described herein. For example, the channel switching module 238 can be configured to determine network traffic associated with the STA 208. Accordingly, the channel switching module 238 may utilize a channel switching protocol to improve network traffic (e.g., uplink traffic and downlink traffic) from the AP 212 to the STA 208. The channel switching protocol includes a protocol for moving between primary and secondary channels. In particular, channel switching module 238 can enable an AP 212 or STA 208 to dynamically switch between channels based on, for example occupation on the primary channel, actual network traffic and/or expected network traffic. For example, the channel switching module 238 can be configured to switch from a primary bandwidth channel to operate on a secondary bandwidth channel

when the primary channel becomes busy due to network traffic that is unrelated to this BSS and is indicated to be busy for at least the next 3 ms. A channel switching circuit or unit may refer to any circuit or circuitry (with or without software) configured to designate one or more devices to communicate on a channel or portion of a channel.

[0057] In various embodiments, channel switching for non-primary channel utilization is executed by channel switching module 238. In particular, the channel switching module 238 can be configured to cause AP 212 or STA 208 to choose channels in accordance with information obtained earlier (e.g., during association) in some embodiments. Channel switching module 238 may operate with or share operations with other components of STA 208 or AP 212 to effect channel selection and non-primary channel utilization in some embodiments.

[0058] With reference to FIG. 3, AP 212 can communicate with STA 204 using a channel 300 in some embodiments. Channel 300 includes a primary channel 302 (e.g., 20 MHz), a secondary channel 304 (e.g., 20 MHz), a secondary channel 306 (e.g., 20 MHz), a secondary channel 308 (e.g., 20 MHz), a secondary channel 310 (e.g., 20 MHz), a secondary channel 312 (e.g., 20 MHz), a secondary channel 314 (e.g., 20 MHz), and a secondary channel 316 (e.g., 20 MHz). Any of secondary channels 304-316 can be a primary control channel, and primary channel 302 can be changed to a secondary channel. Channel 300 can also be apportioned as a single wider bandwidth 340 (e.g., 160 MHz), as a wider bandwidth 330 (e.g., 80 MHz) and a wider bandwidth 332, (e.g., 80 MHz). Channel 300 can also be apportioned as a wider bandwidth 320 (e.g., 40 MHz), a wider bandwidth 322 (e.g., 40 MHz), a wider bandwidth 324 (e.g., 40 MHz), and a wider bandwidth 326 (e.g., 40 MHz). Communications can occur on any channel 302-316 or wider bandwidths 320-340. Channels 302-316 and wider bandwidths 320 -340 can be referred to as channels, sub bands, bandwidths, or bandwidth channels.

[0059] In some embodiments, transmitter 242 is configured to have parallel multiple channel capabilities. Transmitter 242 can include multiple radio components for operating in parallel on multiple channel in some embodiments. In some embodiments, the multiple channel capabilities allow STA 208 to perform full carrier collision avoidance or clear channel assessment (CCA) operations in parallel on multiple channels in its operating bandwidth, including the primary channel (e.g., primary channel 302). If the primary channel is busy, the CCA operation continues on other channels (e.g., secondary channels (e.g., channels 304-316). In some embodiments, STA 208 is configured to perform full CCA operations in parallel on multiple channels, thereby reducing the delay in gaining access to non-primary channels. In some embodiments, the CCA operation is performed on a number N of channels in parallel. The number N can be any integer number (e.g., 2, 4, 5, 8, 16, 32 etc.). In some embodiments, the number N is related to the capabilities of transmitter 242 and receiver 240. Performing CCA oper-

ations in parallel may refer to CCA operations that are at least partially performed on different channels at the same time, nearly the same time, or in a same time period in some embodiments.

[0060] In some embodiments, transmitter 242 may not be configured to have multiple parallel channel capabilities. In some embodiments, the STA 208 is configured to perform full CCA operations (e.g., ED plus virtual CCA and preamble detection) on only one channel at a time. In some embodiments, a transmitter 242 without parallel multiple channel capabilities is configured to perform full CCA operations on other channels after it determines the primary channel is busy and the source and/or destination of the busy channel is not relevant to the STA 208 and/or BSS. In some embodiments, sequential CCA operations (e.g., suitable for devices which cannot perform full CCA in parallel on multiple channels) can delay gaining access on the idle non-primary channels. Performing CCA operations sequentially may refer to CCA operations that are at least partially performed on different channels at different times (e.g., one after the other) in some embodiments. STA 208 is configured to perform sequential CCA operations only during the occupancy of the primary channel (e.g., channel 302) which is determined by examining the duration of the communication of the physical-layer protocol data unit (PPDU) and/or transmission opportunity (TXOP) occupying the primary channel in some embodiments.

[0061] The PPDU may refer to a frame containing a preamble and data fields in some embodiments. The preamble field contains the transmission vector format information in some embodiments. The TXOP may refer to the time duration during which STA 208 can exchange frames after it has gained control of the transmission medium through a contention process in some embodiments. By providing this information regarding expected frame exchange time period, TXOP aims to increase the throughput of high priority data, such as voice and video and to provide virtual medium occupancy information used by other STAs when performing CCA operation.

[0062] In some embodiments, receiver 240 is configured to have multiple parallel channel capabilities. Receiver 240 can include multiple radio components for operating in parallel on multiple channel in some embodiments. Receiver 240 is configured to perform preamble decode in parallel on multiple channels in its operating bandwidth, including the primary channel (e.g., primary channel 302). Accordingly, transmitter 242 can choose any of those non-primary channels (e.g., secondary channels 304-316) for transmitting data to the receiver 240. For a receiver 240 that has a single receive chain for the entire link, once the preamble decode commences on a certain channel, preambles on the remaining channels that are on-air during that brief period of time when the preamble decode is ongoing on one particular channel may not be received. In some embodiments, the receiver 240 is configured to reallocate receiver chain resources away from the primary channel after sufficient

information has been decoded by the receiver chain to determine the duration of the primary channel occupancy and the relevance of the busy channel, where relevance is at least partially determined by either the identity of the BSS of the STAs involved in the frame exchange that is creating the busy channel condition or where the busy condition is not due to a transmission created by or intended to be received by the intended peer of STA 208.

[0063] In some embodiments, receiver 240 may not be configured to have multiple parallel channel capabilities. Receiver 240 may be configured to perform a preamble decode operation on only one channel at a time in some embodiments. In some embodiments, receiver 240 is configured to perform preamble decode operations on other channels after receiver 240 or STA 208 determines the primary channel is busy. In some embodiments, a STA 208 that cannot perform preamble decode operations in parallel on multiple channels performs a sequential preamble decode operation. A sequential preamble decode operation can limit the flexibility of transmitter 242 (of another device) choosing any of the non-primary channels for transmitting data to the receiver 240. In some embodiments, once STA 208 determines that the primary channel becomes occupied by non-relevant devices (for example, devices that are not members of the same BSS as the receiver 240) and the receiver 240 has decoded sufficient information to determine the duration of the primary channel occupancy, then the receiver 240 may switch to alternative channel(s) for possible reception on those channel(s). Non-relevant devices may refer to any devices that are not engaged in frame exchanges involving the intended peer of STA 208 in some embodiments. STA 208 and AP 212 can have a receiver and a transmitter with the respective capabilities of receiver 240 and transmitter 242 discussed above.

[0064] Performing preamble decode operations in parallel may refer to preamble decode operations that are at least partially performed on different channels at the same time, nearly the same time, or in a same time period in some embodiments. Performing a preamble decode operations sequentially may refer to preamble decode operations that are at least partially performed on different channels at different times (e.g., one after the other) in some embodiments.

[0065] Non-primary channel utilization operations are discussed below with respect to a transmitting device 404 and receiving device 408 with reference to FIG. 4. In some embodiments, the transmitting device 404 is a STA or AP, such as, STAs 202, 204, 206, and 208 and APs 212, 214, and 216 operating according to an 802.11 standard as modified herein. In some embodiments, the receiving device 408 is a STA or AP, such as STAs 202, 204, 206, and 208 and APs 212, 214, and 216 operating according to an 802.11 standard as modified herein. In some embodiments, receiving device 408 and transmitting device 404 include similar components.

[0066] Transmitting device 404 includes a processing circuit or other circuitry configured to provide the opera-

tions as described herein. In some embodiments, transmitting device 404 includes a memory or storage device 410 for storing capabilities of device 404 and other devices including receiving device 408, a memory or storage device 410 for storing channels for use in non-primary channel utilization, and a CCA module 414 for CCA operations. In some embodiments, receiving device 408 includes a memory or storage device 410 for storing capabilities of device 408 and other devices including transmitting device 404, a memory or storage device 410 for storing channels for use in non-primary channel utilization, and a decode module 414 for preamble decode operations.

[0067] When the receiving device 408 receives an indication of some external OBSS (Overlapping BSS) (e.g., detects a preamble from another set of devices outside the network), the receiving device 408 assumes that the transmitting device 404 also has detected the OBSS and moves to the next channel in a particular order for the transmission. To lower the probability that the transmitting device 404 has not detected the OBSS while the receiving device 408 has and vice versa, a threshold for detecting the OBSS can be increased. For example, the threshold for signal strength from the OBSS can be increased to increase the probability that both the receiving device 408 and transmitting device 404 detect the OBSS. In some embodiments, the threshold is set at -72 dBm and can be increased to -62dBm.

[0068] In some embodiments, if the channels can be decoded in parallel, a set delay for the receiving device 408 can be used for a retuning operation to start listening on multiple channels. If the channels can be decoded serially, then the receiving device 408 has to switch from one channel to the other, and the delay can be different. A set of delays can be provided for the retuning operation. In some embodiments, operations and capabilities including receiver and transmitter capabilities and/or anchor channels are provided during association (at the beginning of association). Such information can be provided in messages of frames (e.g., management frame provided during association). A retune or retuning may refer to an operation where radio a component is set to a different frequency or bandwidth from its current frequency or bandwidth in some embodiments.

[0069] In some embodiments, the transmitting device 404 and receiving device 408 can operate according to a first non-primary channel utilization operation if the receiving device 408 is configured to have parallel multiple channel capabilities and the transmitting device 404 is configured to have parallel multiple channel capabilities or is configured to perform full CCA operations (i.e. ED plus virtual CCA and preamble detection) on only one channel at a time. According to the first non-primary channel utilization operation, non-primary channel utilization is possible if the receiving device 408 supports preamble decode operations on multiple channels in parallel. In the first non-primary channel utilization operation, the transmitting device 404 and the receiving device 408 agree

on a set of anchor channels. The set can be determined based upon information exchanged between the receiving device 408 and the transmitting device 404 in some embodiments. The information can include capability information related to the capabilities of respective transmitter 242 and receivers 240. The information can be exchanged during association or authentication, in response to requests, during synchronization, or in other handshaking operations in some embodiments. Anchor channels can refer to any channels determined to be used for non-primary channel utilization in some embodiments. The anchor channels can be provided as a list during association or handshaking of two devices in some embodiments. An anchor channel can be a bandwidth associated with a wider bandwidth that serves a channel for the wider bandwidth. An anchor channel can be channel on which beacon and other broadcast frames are transmitted in some embodiments. All PPDU transmission do not necessarily include an anchor channel.

[0070] According to one example, if transmitting device 404 is capable of performing CCA in parallel over four 20MHz channels and the receiving device 408 is capable of receiving preambles in parallel over four 20MHz channels and the operating bandwidth is 80MHz (e.g., four 20MHz channels), there is no anchor channel. The transmitting device 404 is free to transmit on any 20MHz channel and the receiving device 408 is able to decode the transmission. If the operating bandwidth is 160MHz (e.g., eight 20MHz channels) as opposed to 80 MHz, parallel operation covers 80MHz of the 160MHz operating bandwidth in one example. In some embodiments, the transmitting device 404 and the receiving device 408 can split the bandwidth into four groups of 40MHz of bandwidth, where each 40MHz bandwidth has one 20MHz anchor channel. In some embodiments, out of the 8 channels (e.g., operating bandwidth of 160MHz), the transmitting device 404 and the receiving device 408 select four channels which serve as anchor channels and can operate in parallel where the receiving device 408 attempts to decode preambles. Any transmission can include at least one of these four channels. The other four channels can be included as long as the transmission uses at least one of the anchor channels which allows the receiving device 408 to detect and decode the preamble.

[0071] The number of anchor channels is less than or equal to the number of channels on which the receiving device 408 supports parallel preamble decode operations in some embodiments. In some embodiments, the number of anchor channels is more than the number of channels on which the transmitting device 404 supports parallel CCA operations. The anchor channels can be equally spaced in the operating bandwidth of the transmitting/receiving device 408, and the first anchor channel is the primary 20MHz channel in some embodiments.

[0072] In some embodiments, transmissions are provided on at least one of the anchor channels associated with a first non-primary channel utilization operation. In one example where the number of channels on which

the transmitting device 404 supports parallel CCA operations is smaller than the number of anchor channels, the transmitting device 404 can partition the anchor channels into smaller sets with the same number of channels on which the transmitting device 404 supports parallel CCA operations. In some embodiments, the transmitting device 404 starts fresh CCA operations or processes and medium synchronization operations or processes on a first set and moves from one set to the next set if the first set selected is determined to be busy for some minimum duration.

[0073] In some embodiments, a primary 20MHz channel is not a part of a transmission if the primary channel is occupied by an overlapping BSS (OBSS). The primary 20MHz channel is not a part of a transmission only for that duration in first non-primary channel utilization operation in some embodiments. In some embodiments, the perspective of the transmitting device 404 alone matters. Since the receiving device 408 is capable of decoding preambles in parallel on the other anchor channels, the receiving device 408 seeing the OBSS on the primary 20MHz does not adversely affect the first non-primary channel utilization operation in some embodiments. In some embodiments, the receiving device 408 is capable of receiving a preamble on any of those channels irrespective of the primary 20MHz being busy because the number of anchor channels is less than or equal to the number of channels on which the receiving device 408 supports parallel preamble decode operation, and because the anchor channels are negotiated or selected previously.

[0074] In some embodiments, before the transmitting device 404 transmits on any of the anchor channels, the transmitting device 404 allows the receiving device 408 a time gap (e.g., a SameSetDelay parameter) to retune to a state where the receiving device 408 can again decode preambles on all the anchor channels if the transmitting device 404 has detected a preamble on any of the other anchor channels. The SameSetDelay parameter can be negotiated or derived from information received or exchanged between the receiving device 408 and the transmitting device 404 (e.g., during association).

[0075] In some embodiments, the transmitting device 404 and receiving device 408 can operate according to a second non-primary channel utilization operation if the receiving device 408 is configured to have parallel multiple channel capabilities or is configured to perform a sequential preamble decode operation and the transmitting device 404 is configured perform full CCA operations in parallel or is configured to perform full CCA operations (i.e. energy detect (ED) plus virtual CCA) on only one channel at a time. According to the second non-primary channel utilization operation, non-primary channel utilization is possible even if the receiving device 408 supports preamble decoding operations on only one channel at a time. In some embodiments, the receiving device 408 is configured to support preamble decode operations on one channel at a time and is configured to switch to

an alternative channel after determining the relevance and duration of the occupancy (e.g., OBSS occupancy) of the primary channel.

[0076] In some embodiments, the transmitting device 404 and the receiving device 408 agree on an order of using different channels for data exchange without there being any anchor channels in a second non-primary channel utilization operation. In some embodiments, the order is TR1, TR2, etc. where TR1 and TR2 represent data transfers (e.g., on a sequence of channels). In some embodiments, the transmitting device 404 has its own sequence of sets of channels where parallel CCA operations are performed. In some embodiments, the sets are T1, T2, etc., where T1 and T2 are sets of channels. In some embodiments, the transmitting device 404 is configured to perform CCA operations by decoding preambles on the first channel or set of channels in the sequence of channels for data transfer TR1. This set includes the primary 20MHz channel and thus, has overlap with the first channel or set of channels negotiated for data transfer TR1 in some embodiments. If enhanced distributed channel access (EDCA) completes (i.e. the device wins channel access) on any channel that corresponds to TR1, the device transmits on that channel for data transfer TR1 in some embodiments.

[0077] Before transmitting on any channel of the set, if the transmitting device 404 has detected a preamble on any of the channels in data transfer TR1, the transmitting device 404 is configured to allow the receiving device 408 to retune in a time gap corresponding to a SameSetDelay parameter for data transfer TR1 in some embodiments. If no channel that corresponds to data transfer TR1 is available and the primary 20MHz channel is occupied by an OBSS, the transmitting device 404 attempts to transmit on the second channel or set of channels for the data transfer TR2 only for the duration for which the primary 20MHz channel is busy for data transfer TR1 in some embodiments. While attempting transmission on the next set of channels, the transmitting device 404 allows or awaits a time gap corresponding to an OtherSetDelay parameter for the receiving device 408 in some embodiments.

[0078] If the second channel or set of channels for data transfer TR2 is outside of the set of channels T1, the second channel or set of channels is expected to be a part of data transfer TR2 in some embodiments. In that case, the transmitting device 404 needs to start fresh CCA processes on channel T2. Also, in that case, a medium synchronization process is used. Medium synchronization may be performed through enforcement of request to send/clear to send (RTS/CTS) in the beginning of the transmission, usage of a lower CCA threshold or/and setting a limit on the maximum number of failed attempts in some embodiments.

[0079] While the primary 20MHz channel is busy and the second set of channels for data transfer TR2 is also not available, the transmitting device 404 attempts to transmit on the set of channels for data transfer TR3

(starting fresh CCA processes if data transfer TR3 has channels outside of channel T3) in some embodiments. This continues until all channels are seen to be unavailable in some embodiments.

[0080] In some embodiments, control returns to the first set of channels for the data transfer TR1 once the duration determined during decode (e.g. NAV or PPDU length) on the primary 20MHz channel expires. Upon returning to the primary 20MHz channel, medium synchronization process need not be used if the return is before the expiry of the decoded duration.

[0081] According to one example, the transmitting device 604 and the receiving device 608 operate in a serial manner over multiple sets of channels. In some embodiments, with the same capability as described in the anchor channel example above (the transmitting device 604 being capable of performing CCA in parallel over four 20MHz channels and the receiving device 608 being capable of receiving preambles in parallel over four 20MHz channels), the transmitting device 604 and the receiving device 408 split the channels into two groups of four channels each when the operating bandwidth is 160MHz. The two groups are channels for data transfers TR1 and TR2. When operating on group TR1, the transmitting device 404 and the receiving device 408 can exchange data on any of the four 20MHz channels of TR1 without any anchor channels. When none of the channels of group TR1 are available, the operation moves to group TR2 and there are no anchor channels in any set. In some embodiments, where the transmitting device 404 and the receiving device 408 capable of supporting CCA/preamble decode on only one channel at a time (e.g., non-parallel operations), each group TR1, TR2, etc. will contain only one channel each (e.g., there will be eight sets of one channel each).

[0082] A network allocation vector (NAV) can refer to a virtual carrier-sensing mechanism used with wireless network protocols such as IEEE 802.11 (Wi-Fi) and IEEE 802.16 (WiMax). The virtual carrier-sensing can be a logical abstraction which limits the need for physical carrier-sensing at the air interface of a listening device that is performing CCA in order to save power and to allow determination of a busy channel where the occupying transmission might not be detectable by a listening device due to the topographical relationship between the transmitting and listening devices. The MAC layer frame headers contain a duration field that specifies the transmission time required for the transmission of one or more frames of a frame exchange, during which time the medium will be busy. The STAs listening on the wireless medium read the duration field and set their NAV, which is an indicator for a station on how long it must defer from accessing the medium in some embodiments.

[0083] The NAV uses a counter which counts down to zero at a uniform rate in some embodiments. When the counter is zero, the virtual carrier-sensing indication is that the medium is idle; when nonzero, the indication is busy. The medium or channel is generally determined to

be busy when the STA is transmitting. In IEEE 802.11, the NAV represents the number of microseconds the sending STA intends to hold the medium busy for its transmission and any responding transmission made by its intended recipient STA and optionally additional such exchanges (maximum of 32,767 microseconds). When the sender sends a request to send (RTS) the receiver waits one short interframe space (SIFS) before sending CTS. The sender will wait again an SIFS before sending a data-bearing or management frame. Again the receiver will wait a SIFS before sending an ACK or block ACK or no response. NAV is the duration from the first SIFS to the ending of ACK or block ACK in some embodiments. Additional exchanges of such exchanges may occur within SIFS of the end of the ACK or block ACK. During this time the medium is considered busy. SIFS may refer to the amount of time in microseconds required for a wireless interface to process a received frame and to initiate a response transmission with a response frame in some embodiments.

[0084] The second non-primary channel utilization operation uses a common understanding between the transmitting device 404 and receiving device 408 of the primary 20MHz channel being occupied by OBSS and of any other channels being not available. In some embodiments, the transmitting and receiving device 408s attempt to detect the same OBSS on the primary 20MHz channel and then move to the next set of channels. The signal strength from the OBSS is compared to a threshold to detect the OBSS. In some embodiments, the threshold is set to increase the probability that both transmitting device 404 and receiving device 408 detect the OBSS. In some embodiments, the threshold is set to less than -62dBm or -72 dBm. Similarly, other channels can be determined to be busy or idle by comparing signal strength on the channel to a threshold (e.g., greater than or less than -62dBm (or -72 dBm), respectively) in some embodiments. In some embodiments, the transmitting device 404 and/or receiving device 408s detect an OBSS or other busy activity by detecting if there is an indication transmitted through a control link. If a control link exists, and an indication is transmitted on the control link to switch to another channel, the transmitting device 404 moves to another channel in the set of channels. In some embodiments, the transmitting device 404 and/or receiving device 408s detect an OBSS or other busy activity in response to identification information within the preamble and/or MAC portion of a frame. In some embodiments, this detection scheme is used in a coordinated system.

[0085] With reference to FIG. 5, a flow 500 can be performed in system 200 for a transmitting device non-primary channel utilization setup operation in some embodiments. Flow 500 is for a transmitting device and includes an operation 502. At operation 502, the transmitting device determines if non-primary channel transmission is supported. If not, flow 500 ends. If so, the transmitting device advances to an operation 503.

[0086] At operation 503, transmitting device deter-

mines the number of channels (e.g., 1, 2, 3, 4, 8, etc.) that can support CCA operations in some embodiments. If the transmitting device can only support one channel for CCA operations, the transmitting device determines the order in which CCA operations are supported on the channels in operation 504 in some embodiments. If the transmitting device can support more than one channel for CCA operations, the transmitting device determines channels for supporting CCA operations in parallel in operation 508 in some embodiments. If all channels do not support CCA operations, an order in which CCA operations are supported on multiple sets of channels is determined in operation 508 in some embodiments.

[0087] With reference to FIG. 6, a flow 600 can be performed in system 200 for a receiving device 408 non-primary channel utilization setup operation in some embodiments. Flow 600 is for a receiving device 408 and includes an operation 602. At operation 602, the receiving device 408 determines if non-primary channel reception is supported. If not, flow 600 ends. If so, the receiving device 408 advances to an operation 603.

[0088] At operation 603, receiving device 408 determines the number of channels (e.g., 1, 2, 3, 4, 8, etc.) that can support preamble decode operations in parallel in some embodiments. If the receiving device 408 can only support one channel for CCA operations, the receiving device 408 determines the order in which preamble decode operations are supported on the channels in operation 604. A delay required for moving from one channel to the next (e.g., the SameSetDelay parameter) can be determined in operation 606. If the receiving device 408 can support more than one channel for preamble decode operations, the receiving device 408 determines channels for preamble decode operations in parallel in operation 608 in some embodiments. If all channels do not support preamble decode operations, an order in which preamble decode operations are supported on multiple sets of channels is determined in operation 608 in some embodiments. In some embodiments, in operation 608, even if multiple channels support preamble decode in parallel, the receiving device 408 determines whether simultaneous preamble decode is supported on the multiple channels. If not, the delay required to come out of a preamble decode on one channel corresponding to a not-to-self packet is determined in an operation 610 in some embodiments. Delays can be determined based upon device capabilities and operating parameters.

[0089] In some embodiments, the capability negotiation in flows 500 and 600 allow the transmitting device and the receiving device 408 to determine, negotiate and/or agree on a number of parameters for non-primary channel utilization operations. For example, parameters can include an indication whether or not to exercise non-primary channel exchange, a parallel/sequential order in which non-primary channel exchange is performed, a time gap (e.g., SameSetDelay parameter) parameter needed at the receiving device 408 between preambles on two different channels of the same set in order to suc-

cessfully decode the preambles, a time gap needed at the receiving device 408 between preambles on two channels of two different sets in order to successfully decode the preambles (e.g., OtherSetDelay parameter), etc.

[0090] Examples of parallel/sequential order in which non-primary channel exchange is performed include Set 1: channels 1, k+1, 2k+1, ... (TR1); Set 2: channels 2, k+2, 2k+2, ... (TR2); etc. Examples of SameSetDelay parameters include 0 microseconds (us), 50 us, 100 us, 200 us etc. Examples of OtherSetDelay parameters include 0 us, 50 us, 100 us, 200 us etc.

[0091] In some embodiments, during transmit on one channel, blindness on all other channels is assumed. During receive on one channel, blindness on any other channels is determined. If blindness on a channel is not aligned with a known virtual current sense (NAV), a medium synchronization process is used. A synchronization process timer is initiated when the blindness ends at the end of the transmission or reception, with a timer duration set for conservative behavior upon returning from the channel. A lower energy detect (ED) threshold value can be used in some embodiments to make the returning device more sensitive to detecting an ongoing transmission while the timer is running.

[0092] Transmitting on any subset of channels of a link renders the transmitting device blind on the channels that are left out from the perspective of preamble detection. Anytime that a transmitting device is blind on a set of channels for the purpose of the CCA operation, the transmitting device performs conservative access measures on returning to it so as not to penalize the already transmitting devices in some embodiments. In some embodiments, anytime that a transmitting device is blind on a set of channels for a CCA operation, the transmitting device performs conservative access measures on returning to the set for channels so that other transmitting devices are not penalized.

[0093] In some embodiments, a number of implementations of flows 500 and 600 can operate simultaneously in communication system 200. Flows 500 and 600 can be performed in firmware executing on the hardware of STAs 202, 204, and 206 and APs 212, 214, and 216. The firmware can operate in a layer of a protocol stack or the MAC layer of STAs 202, 204, and 206 and/or APs 212, 214, and 216.

[0094] It should be noted that certain passages of this disclosure can reference terms such as "first" and "second" in connection with subsets of frames, response, and devices, for purposes of identifying or differentiating one from another or from others. These terms are not intended to relate entities (e.g., a first device and a second device) temporally or according to a sequence, although in some cases, these entities can include such a relationship. Nor do these terms limit the number of possible entities (e.g., STAs, APs, beam formers and/or beam formees) that can operate within a system or environment. It should be understood that the systems described

above can provide multiple ones of any or each of those components and these components can be provided on either a standalone machine or, in some embodiments, on multiple machines in a distributed system. Further still, bit field positions can be changed and multibit words can be used. In addition, the systems and methods described above can be provided as one or more computer-readable programs or executable instructions embodied on or in one or more articles of manufacture, e.g., a floppy disk, a hard disk, a CD-ROM, a flash memory card, a PROM, a RAM, a ROM, or a magnetic tape. The programs can be implemented in any programming language, such as LISP, PERL, C, C++, C#, or in any byte code language such as JAVA. The software programs or executable instructions can be stored on or in one or more articles of manufacture as object code. Circuitry may refer to any electronic circuits or circuits.

[0095] While the foregoing written description of the methods and systems enables one of ordinary skill to make and use embodiments thereof, those of ordinary skill will understand and appreciate the existence of variations, combinations, and equivalents of the specific embodiment, method, and examples herein. For example, specific values for bandwidths, channels and sub bands discussed above are exemplary. The present methods and systems should therefore not be limited by the above described embodiments, methods, and examples, but by all embodiments and methods within the scope and spirit of the disclosure.

[0096] While the foregoing written description of the methods and systems enables one of ordinary skill to make and use embodiments thereof, those of ordinary skill will understand and appreciate the existence of variations, combinations, and equivalents of the specific embodiment, method, and examples herein. The present methods and systems should therefore not be limited by the above described embodiments, methods, and examples, but by all embodiments and methods within the scope and spirit of the disclosure.

Claims

1. A first device for communicating with a second device, the first device comprising:

circuitry configured to:

communicate with the second device using a primary channel;
detect occupation on the primary channel by a third device; and
communicate with the second device using a secondary channel in response to the occupation by the third device,

the secondary channel being chosen from a set of channels, the set of channels being deter-

mined at least partially in response to information exchanged during association of the first device and the second device.

2. The first device of the preceding claim, the circuitry is further configured to communicate with the second device using the primary channel when the occupation by the third device is completed.
3. The first device of any one of the preceding claims, wherein the first device comprises a station (STA) device communicating via a protocol employing 20 MHz beacon signals.
4. The first device of any one of the preceding claims, wherein the information comprises a first capability of the first device and a second capability of the second device.
5. The first device of claim 4, wherein the first capability comprises a capability to perform a preamble decode operation in parallel on multiple channels; wherein in particular a number of the channels in the set of the channels is less than or equal to a number of the multiple channels upon which the preamble decode operation is performed in parallel.
6. The first device of any one of the preceding claims 4 to 5, wherein the second capability comprises a capability to perform a clear channel assessment operation in parallel on multiple channels; wherein in particular the clear channel assessment operation comprises a virtual clear channel assessment operation.
7. The first device of any one of the preceding claims 4 to 6, wherein the second capability comprises a capability that does not include a capability to perform a clear channel assessment operation in parallel on multiple channels.
8. The first device of any one of the preceding claims 4 to 7, wherein the second capability comprises a capability to perform a clear channel assessment operation on a single channel, wherein the clear channel assessment operation comprises an energy detect operation and a virtual clear channel assessment operation.

9. The first device of any one of the preceding claims, wherein

the set of channels are channels used for a data transfer;
wherein in particular
the first capability comprises a capability that does not perform a preamble decode operation in parallel on multiple channels.

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10. A first device for communicating on a network, the first device comprising:
circuitry configured to:

communicate using a secondary channel after completing association on a primary channel, wherein the secondary channel is selected at least partially in response to a parameter exchanged during the association, wherein the parameter indicates a capability to perform a preamble decode operation in parallel on multiple channels, a capability to perform a clear channel assessment operation in parallel on multiple channels, a capability for a clear channel assessment that does not perform the clear channel assessment operation in parallel on multiple channels, or a capability for a preamble decode operation that does not perform the preamble decode operation in parallel on multiple channels.

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11. The first device of the preceding claim 10, wherein the first device comprises a station (STA) device communicating via a protocol employing 20 MHz beacon signals.

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12. The first device of any one of the preceding claims 10 to 11, wherein

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the parameter comprises a delay time;
wherein in particular
the delay time is to allow a receiver to retune for preamble detection on a channel and/or the secondary channel is a 20 MHz channel.

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13. The first device of any one of the preceding claims 10 to 12, wherein

the secondary channel is selected from a list of anchor channels determined at least partially in response to the parameter.

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14. A method of switching from a primary channel to a secondary channel, the method comprising:

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associating with a first device using the primary channel;
detect occupation on the primary channel by a second device;
communicating with the first device using the secondary channel at least in response to the occupation by the second device,

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the secondary channel being chosen in response to a parameter exchanged during association using the primary channel, wherein the parameter indicates

a capability to perform a preamble decode operation in parallel on multiple channels,
a capability to perform a clear channel assessment operation in parallel on multiple channels,
a capability for a clear channel assessment that does not perform the clear channel assessment operation in parallel on multiple channels, or
a capability for a preamble decode operation that does not perform the preamble decode operation in parallel on multiple channels.

15. The method of the preceding claim 14, further comprising:

performing a preamble decode operation or a clear channel assessment operation on the secondary channel before communicating with the second device on the secondary channel.

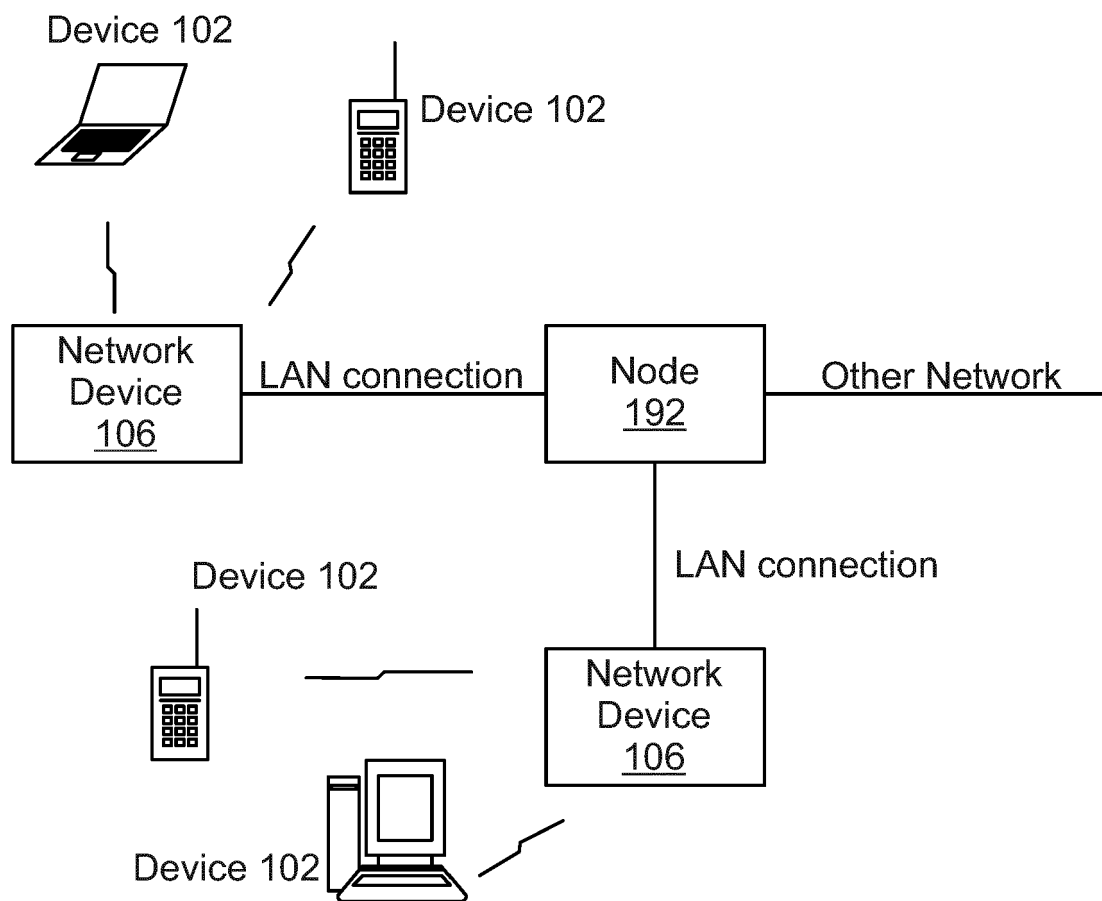


Fig. 1A

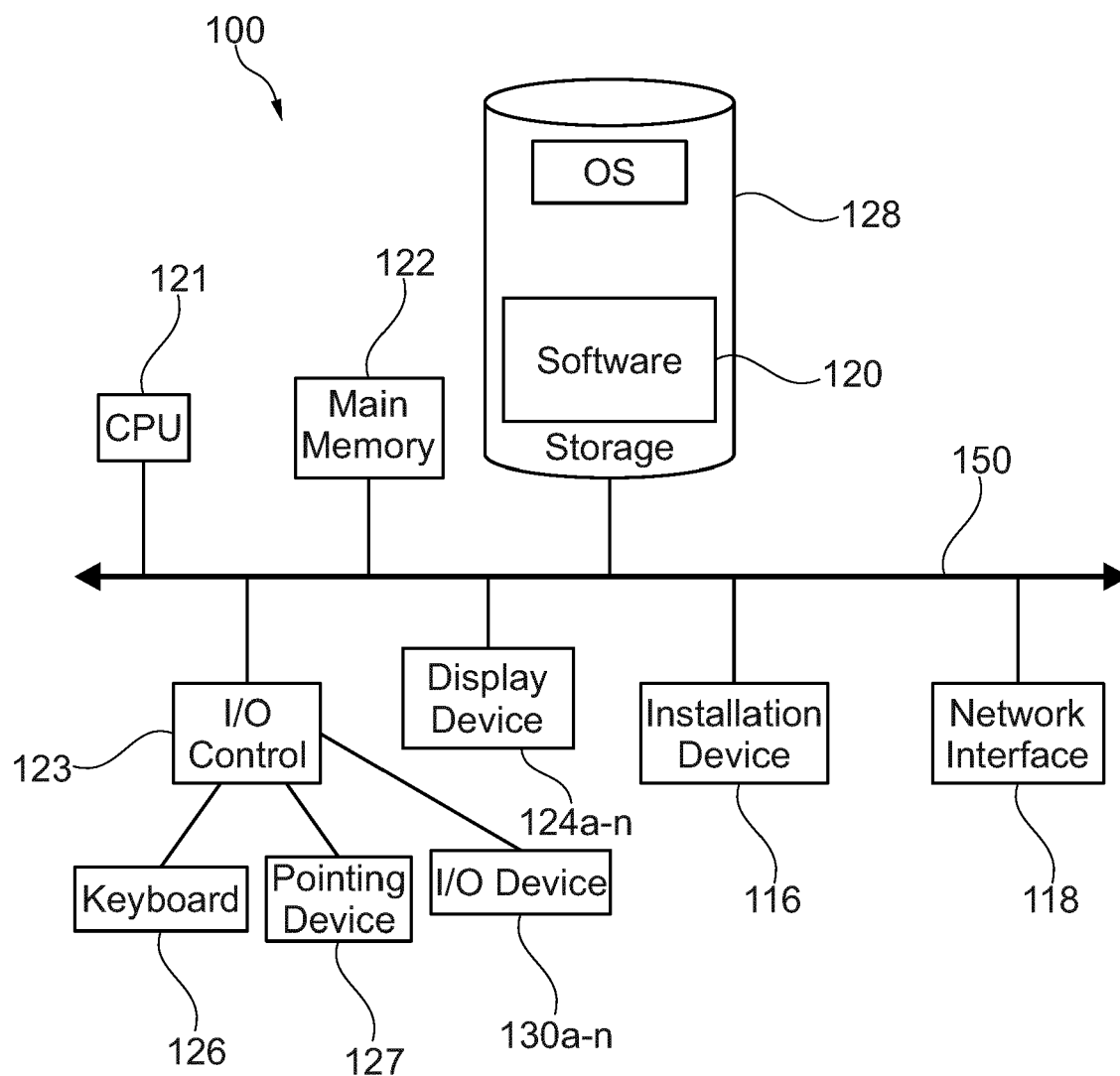


Fig. 1B

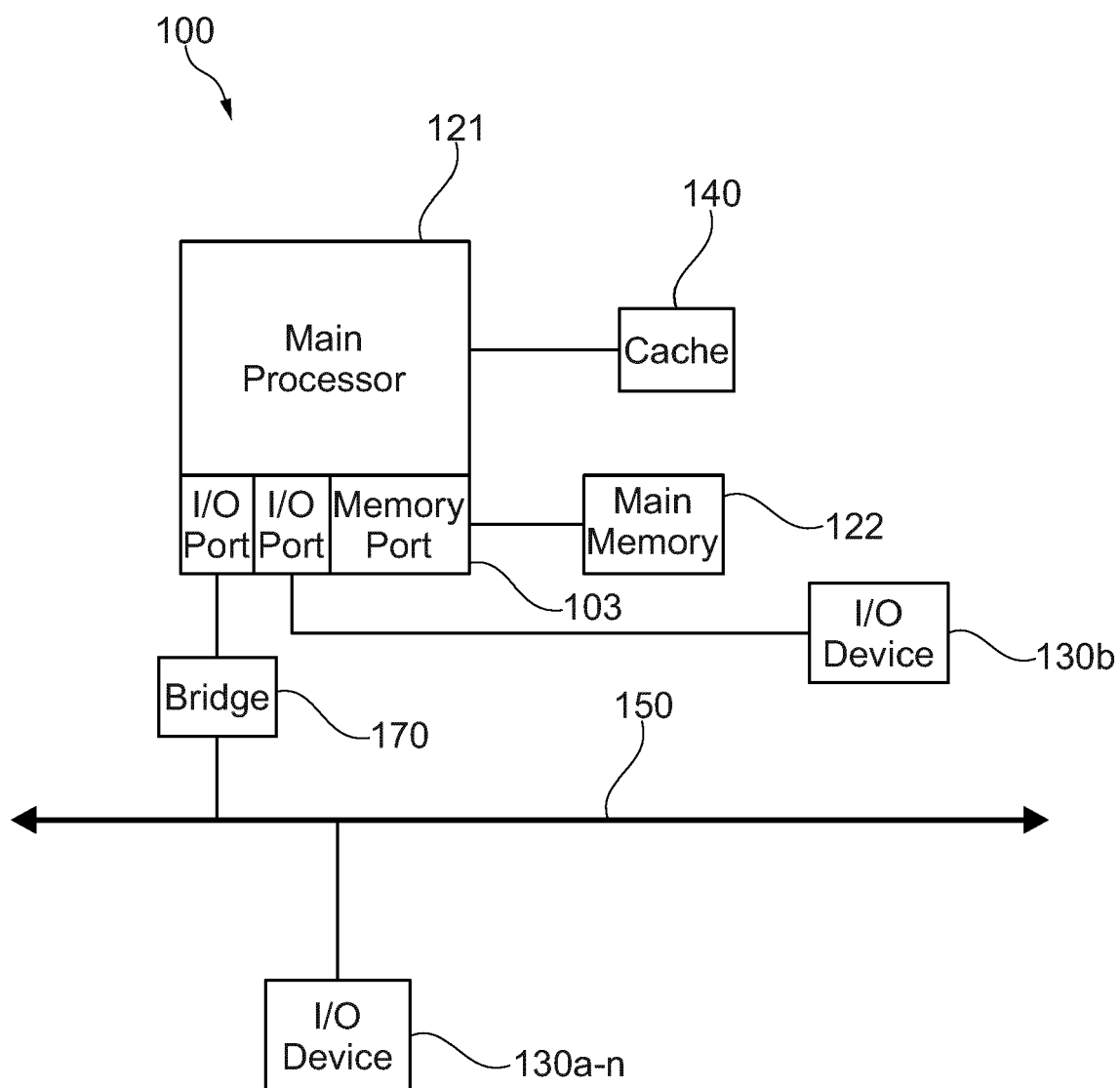


Fig. 1C

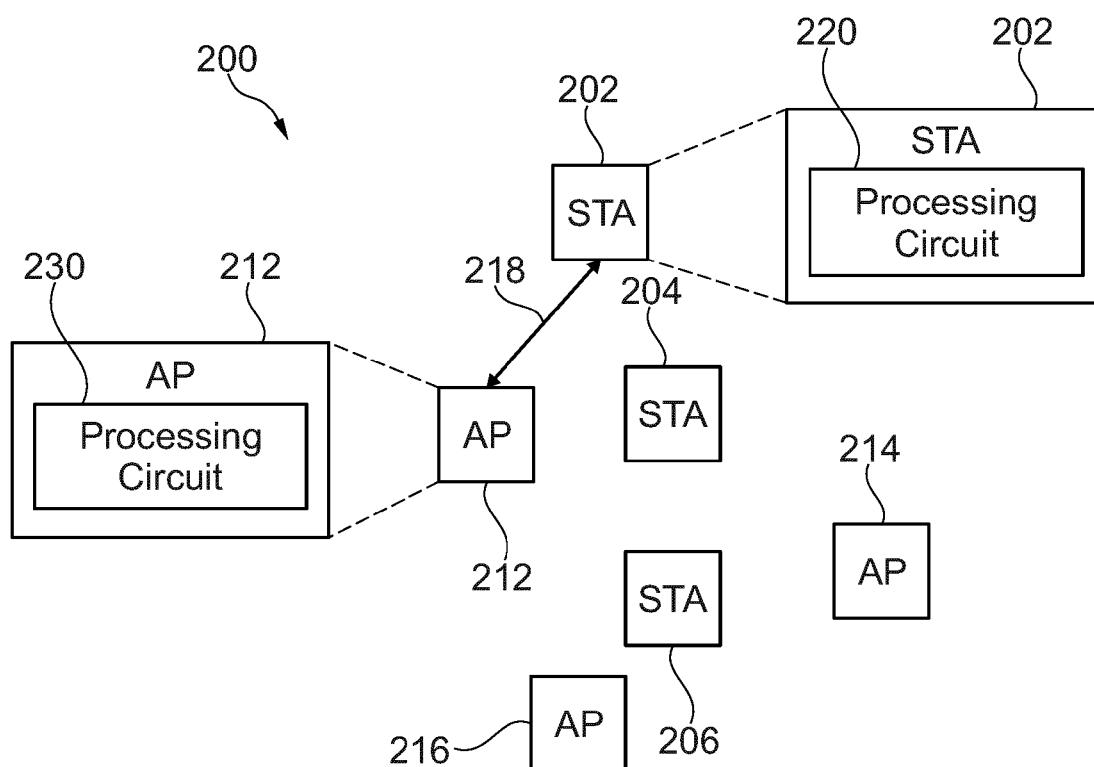


Fig. 2A

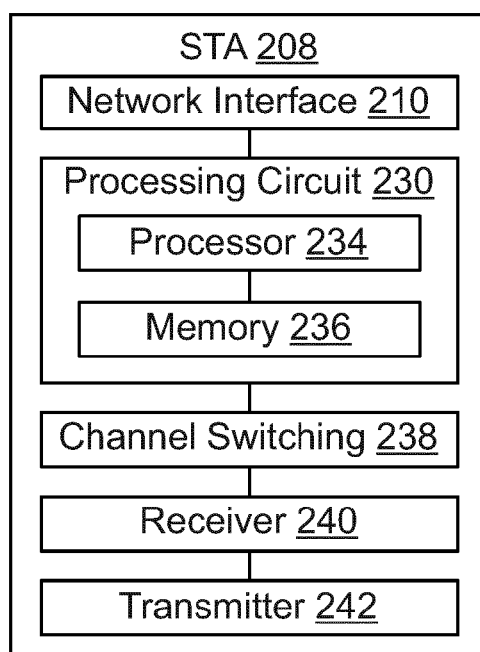


Fig. 2B

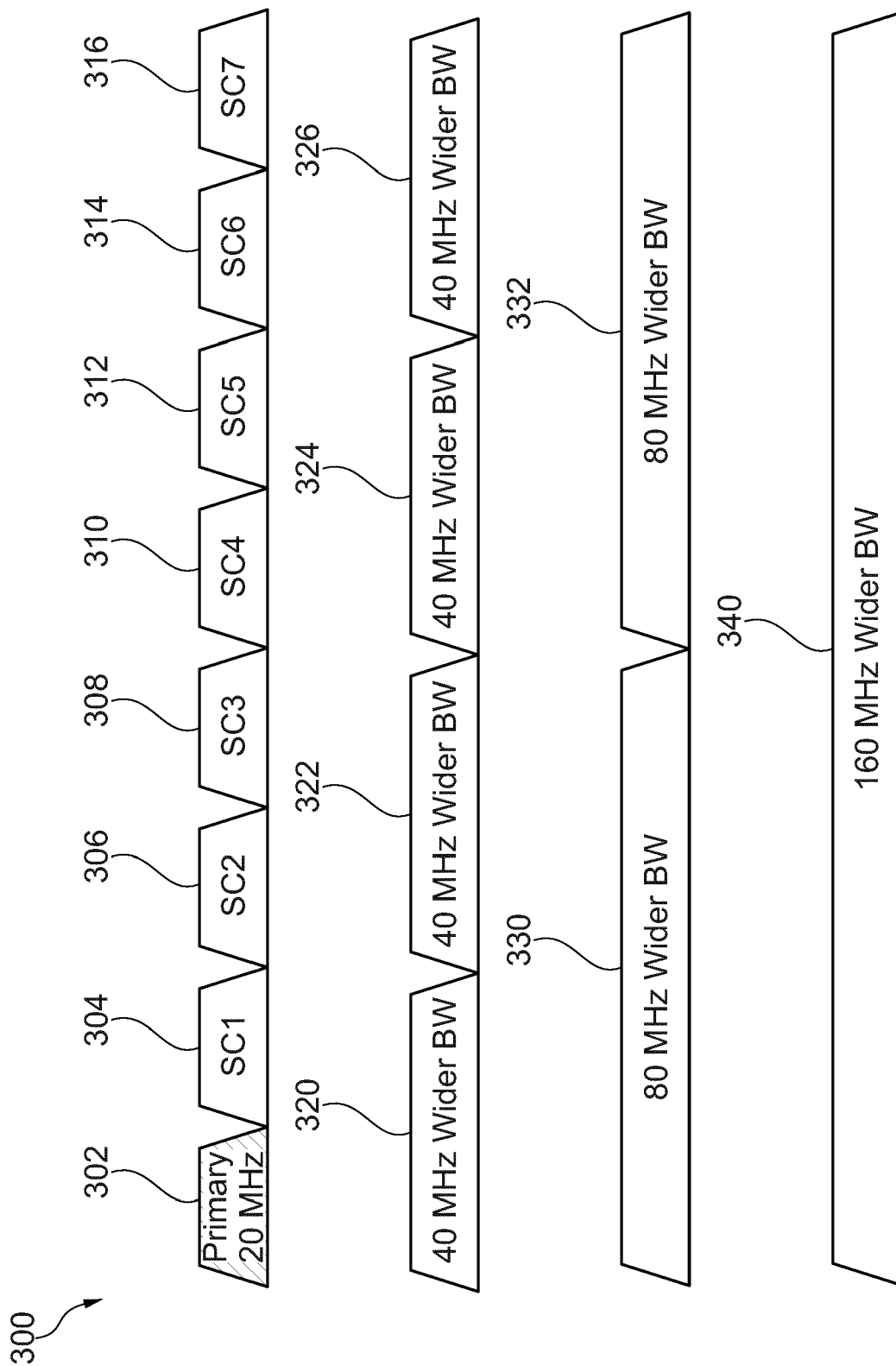


Fig. 3

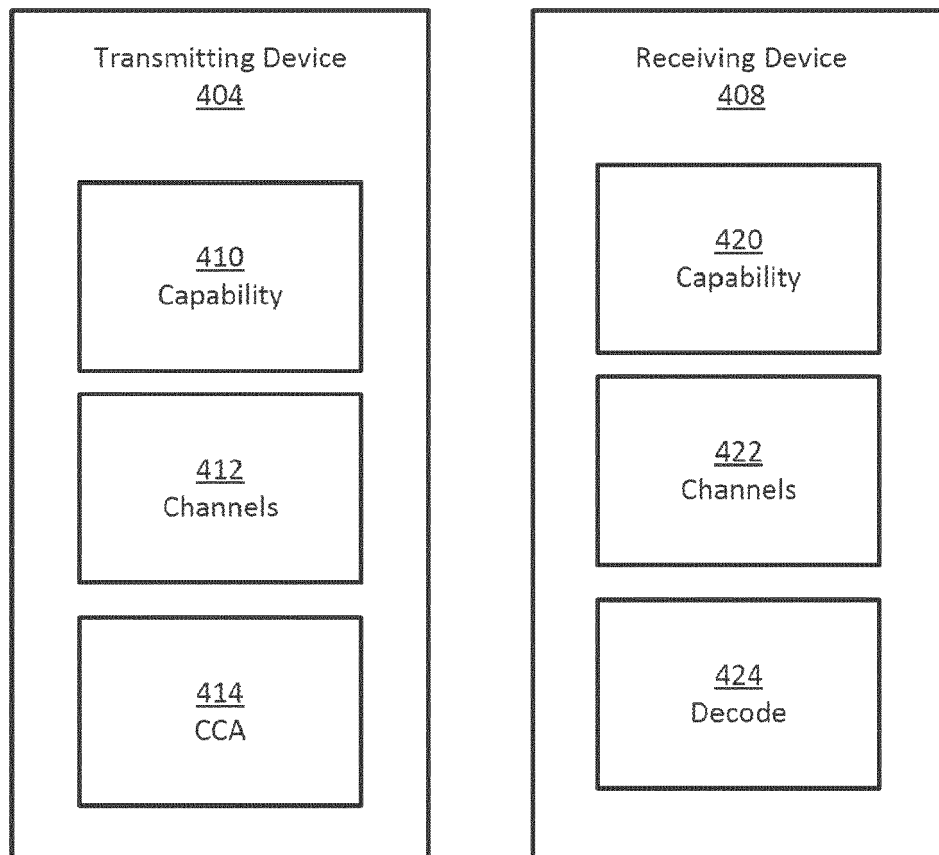


FIG. 4

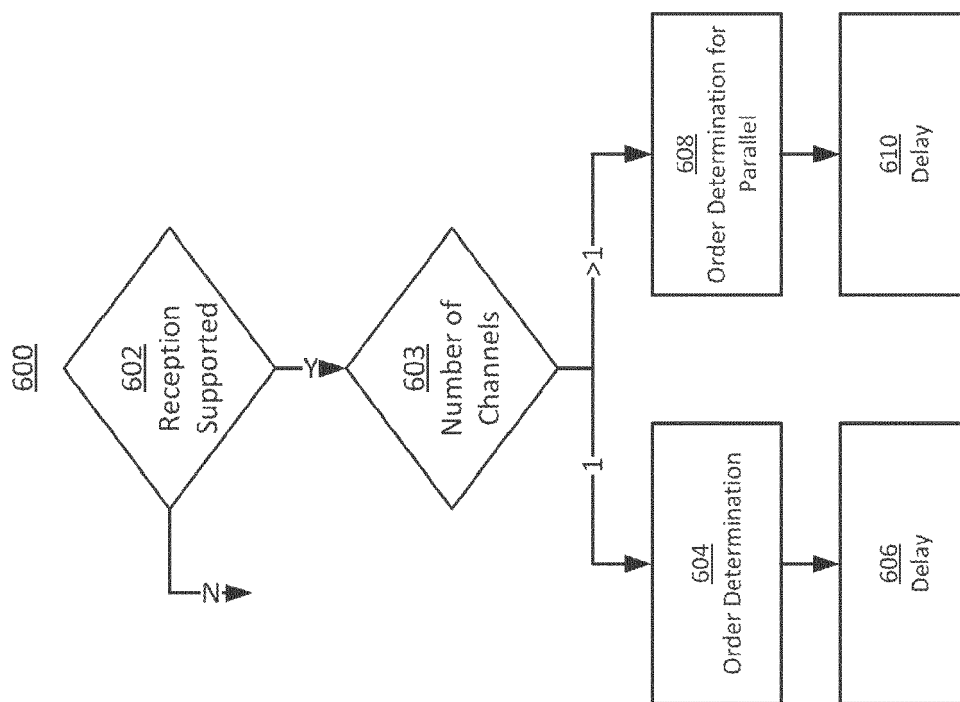


FIG. 6

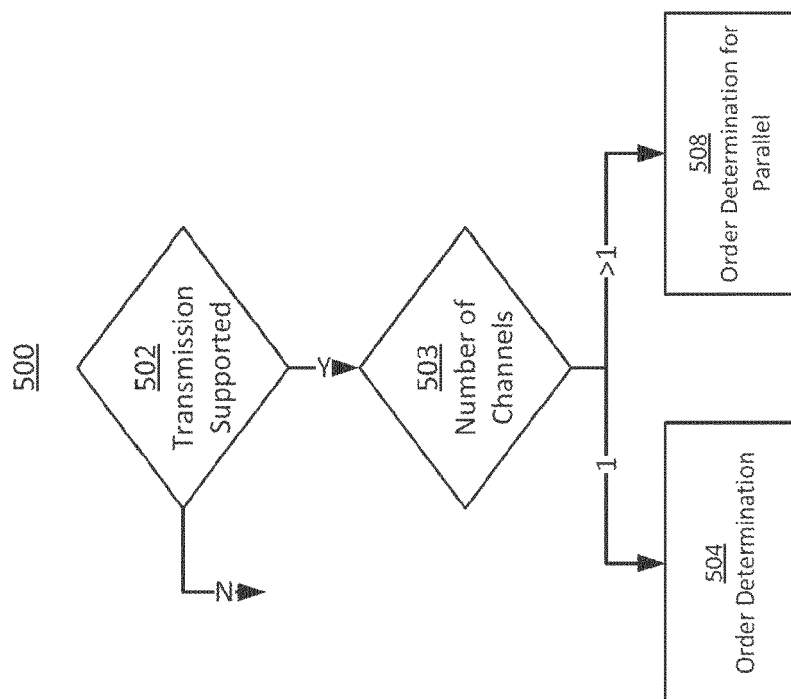


FIG. 5



EUROPEAN SEARCH REPORT

Application Number

EP 23 20 9115

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	<p>SINDHU VERMA (BROADCOM): "Proposals on unused bandwidth utilizations", IEEE DRAFT; 11-20-0363-03-00BE-PROPOSALS-ON-UNUSED-BANDWIDTH-UTILIZATIONS, IEEE-SA MENTOR, PISCATAWAY, NJ USA</p> <p>, vol. 802.11 EHT; 802.11be, no. 3 26 August 2020 (2020-08-26), pages 1-18, XP068172278, Retrieved from the Internet: URL:https://mentor.ieee.org/802.11/dcn/20/11-20-0363-03-00be-proposals-on-unused-bandwidth-utilizations.pptx [retrieved on 2020-08-26] * page 4 - page 5 * * page 7 - page 9 *</p>	1-15	<p>INV. H04W74/0808 H04W28/08</p>
A	<p>SINDHU VERMA (BROADCOM): "Proposals on unused bandwidth utilizations", IEEE DRAFT; 11-20-0363-00-00BE-PROPOSALS-ON-UNUSED-BANDWIDTH-UTILIZATIONS, IEEE-SA MENTOR, PISCATAWAY, NJ USA</p> <p>, vol. 802.11 EHT; 802.11be 15 March 2020 (2020-03-15), pages 1-5, XP068167058, Retrieved from the Internet: URL:https://mentor.ieee.org/802.11/dcn/20/11-20-0363-00-00be-proposals-on-unused-bandwidth-utilizations.pptx [retrieved on 2020-03-15] * the whole document *</p>	1-15	<p>TECHNICAL FIELDS SEARCHED (IPC)</p> <p>H04W H04L</p>
The present search report has been drawn up for all claims			

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EPO FORM 1503 03:82 (P04C01)

Place of search

The Hague

Date of completion of the search

22 February 2024

Examiner

Machado Costa, M

CATEGORY OF CITED DOCUMENTS

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D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document



EUROPEAN SEARCH REPORT

Application Number

EP 23 20 9115

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	"IEEE Standard for Information Technology--Telecommunications and Information Exchange between Systems Local and Metropolitan Area Networks--Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 1: Enhancements for High-Efficiency WL", IEEE STANDARD, IEEE, PISCATAWAY, NJ USA / 19 May 2021 (2021-05-19), pages 1-767, XP068181575, DOI: 10.1109/IEEESTD.2021.9442429 ISBN: 978-1-5044-7389-7 Retrieved from the Internet: URL:https://ieeexplore.ieee.org/document/9442429 [retrieved on 2021-05-26] * the whole document * -----	1-15	
			TECHNICAL FIELDS SEARCHED (IPC)
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		22 February 2024	Machado Costa, M
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	
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